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Progress Toward an Updated National Solar Radiation Data Base

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Progress Toward an Updated National Solar Radiation Data Base

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ABSTRACT

Progress is reported on an updated National Solar Radiation Database (NSRDB). Focus on this year's work was on preparing a test-year database for evaluating several solar radiation models that could be used to replace the METSTAT model used in the original 1961-1990 NSRDB. That model is no longer compatible with cloud observations reported by the National Weather Service. We have also included a satellite-based model that will increase the spatial resolution of solar radiation for GIS or mapping applications. Work also included development of improved estimates for aerosols, water vapor, and ozone. High-quality solar measurements were obtained for 33 sites near National Weather Service stations, and model runs were completed for test years 1999 and 2000.

1. Objectives

This project addresses solar resource assessment, access to data, and characterization of the solar resource, as well as the needs of designers, modelers, and resource assessment interests. Further, the project breaks new ground with the incorporation of satellite imagery in the modeling of solar resource assessment data.

The effort described here contributes toward an update of the 1961-1990 National Solar Radiation Data Base [1]. We produced a small-scale evaluation database, enabling us to investigate database production issues, assess input data availability and quality, and develop modeling alternatives.

The year's work forms the groundwork necessary for a report of recommendations on the feasibility of and preferred methods for producing an updated database. That report will provide the U.S. Department of Energy and other interests with the information necessary to allocate resources for a full-scale NSRDB update.

2. Technical Approach

The project acquired all necessary solar, satellite imagery, and meteorological input files necessary for model runs and evaluations:

- Acquire and quality-assess available measurements of solar irradiance data for validation
- Research data-filling methods (for missing periods of input meteorological data)
- Modify the METSTAT solar model inputs for automated meteorological data and satellite cloud product
- Evaluate the American Society of Heating, Refrigeration, and Air-conditioning Engineers (ASHRAE) model (using automated and satellite cloud inputs)
- Produce a gridded solar product using State University of New York at Albany (SUNYA) satellite model
- Investigate feasibility of new clear-sky algorithms for solar models
- Develop improved atmospheric aerosol and water-vapor estimates
- Quantify differences between the original NSRDB methods and update methods.

3. Results and Accomplishments

METSTAT Model – The recent switch to automatic weather service stations eliminated the human observed total and opaque sky cover amounts used for inputs to the METSTAT model. The approach used for this year's work derived equivalent sky cover inputs (total and opaque cloud cover) from a combination of Automated Surface Observing System (ASOS) and ASOS supplemental cloud measurements. ASOS detects clouds to 12,000 feet, whereas the ASOS supplemental cloud measurements provide information about clouds for heights above 12,000 feet. The ASOS supplemental cloud measurements are derived from GOES satellite data.

ASHRAE/NRCC Model – ASHRAE and the Northeast Regional Climate Center have developed a solar radiation model for applications in the architectural community [2]. Their approach was to modify a model developed for estimating global horizontal radiation for the northeast region of the United States.

Essentially, the model consists of closed-form transmittance equations for Rayleigh, gas, and water vapor transmission (estimated from dew point), and a look-up table of empirical expressions for aerosol transmission and cloud transmissions to computed global and direct irradiance. Diffuse irradiance is computed from these two estimated components.

SUNYA Satellite Model – One goal of the updated NSRDB is a spatial resolution greater than the ancillary interpolated products that were later produced based on the 239 NSRDB meteorological stations. Toward that end, we are considering using a model that estimates solar radiation from satellite imagery. The Atmospheric Sciences Research Center (ASRC) at SUNYA has been developing such a

model that derives 10-km-pixel solar estimates based on differences between a pixel's clear-sky reflectance as seen by the satellite and the brighter values that occur with increasing cloud reflectance of incoming solar radiation.

The SUNYA model has been refined to take into account anomalous ground conditions that occur either geographically (specular reflections from bright sand or water) or with time (snow cover). Perez et al. [3] have shown that the refined model, when compared with 13 ground measurement stations, has an average mean bias error (MBE) in global irradiance of 3 W/m^2, (less than 1% of the average irradiance) and an average root mean square error (RMSE) of 54 W/m^2 (14%). The errors for direct normal estimates are an MBE of 4 W/m^2 (1%) and RMSE of 137 W/m^2 (30%).

Analysis – The three models described above have been run using the available input data to produce modeled solar radiation data for the 33 station test sites. The resulting output data set holds a total of 396 station months, or 245,909 daylight station hours available for comparison with the measured data in the test sites. Because the objective of the project is to produce a database of solar radiation with the same statistical properties as the measured data, our primary focus for model performance is not on hour-by-hour comparisons of model and measured data, but comparison of appropriate statistics for the measured and modeled data. Note this was the objective of the original NSRDB: the philosophy being that even if there were great discrepancies in hour-by-hour modeled data with respect to measured data (if it were available), if the model data set provided the correct statistics (mean, variance) for monthly solar radiation data, then hourly simulations using this data over periods of a month to a year to many years would result in correct computation of simulation results.

Preliminary investigations will look at the clear-sky envelopes, which are the basis of the model computations, in comparison with measured clear-sky data to discern possible inherent biases between the models. We will then investigate MBE, RMSE, scatter plots and correlations between measured and modeled data, the difference between measured and modeled data as a function of measured irradiance, and as cumulative probability functions as in Fig. 1.

We will intensively investigate the hypothesis that the difference between monthly means of daily total and hourly average modeled and measured solar radiation is zero.

4. Conclusions

With the work accomplished this year, we are now in a position to evaluate model performance and quantify the feasibility of producing an updated NSRDB. By examining tools, input data availability, processing constraints, and uncertainties of the output product, we will be able to develop a NSRDB update plan.

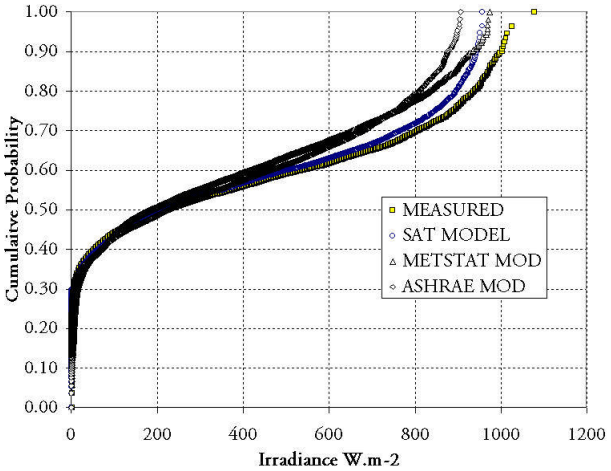

Figure 1. Preliminary cumulative probability plots for two years of hourly measured global horizontal [squares] and three model data sets (satellite: circles; METSTAT: triangles; ASHRAE: diamonds) for a single test site.

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R. Perez, et al., "Status of High Resolution Solar Irradiance Mapping from Satellite Data," *Proceedings of the American Solar Energy Society, July 2004, Portland OR*.

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